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Review Article

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Membrane Technology for Water and Wastewater Management and Application in Egypt

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MEMBRANE (MBR) technology has become a key component in water reclamation schemes due to the possibility of providing water of high quality,(*e.g.* as particle-free permeate from membrane bioreactors, removal of microbiological contaminants). Besides, it is a cost-effective technique to obtain a remediated effluent. In Egypt, we are in stringent need to boost water recycling applications for the target area as well as in other regions of the world. It has been used for various treatment applications for more than 30 years. Membrane costs have declined; successfully; by an order of magnitude over the past two decades. The MBR process was demonstrated to be cost-effective over conventional water reclamation systems for urban irrigation and water reuse.

The MBRs are fast developing new concepts for water and wastewater treatment. MBR leads to high hygienic standards of the treated effluent. MBRs are ecologically friendly and economically feasable for applications in remote areas. Over the last two decades, variable types of MBRs were developed including the size of pilolt plants and real wastewater treatment plants. literatures proved that industrial, domestic, and municipal wastewaters were treated efficently by membrane technologies. Furthermore, MBR technology is a very promising water treatment technology and could be used as an efficient tool for wastewater. MBR was employed for the treatment of both, grey-water and black-water. Results exhibited high efficiency of MBR for wastewater treatment. Thus, the high effluent quality opens a variety of different options for safe water reuse in irrigation and / or toilet flushing. There are a number of benefits associated with MBRs compared to conventional wastewater treatment processes. Therefore, excellent effluent quality can be obtained generally suitable for reuse as membranes provide high removals of pathogens including bacteria, protozoa and viruses resulting in excellent physical disinfection. The purpose is unrestricted water reuse for non-potable purposes. Several treatment technologies are available to transfer the manmade polluted water to be safe reuse as an additional amount to our water budget.

The objective of the present study is to represent the promising efficiency of MBR as biotechnology for the treatment of water and wastewater as a promising technique. Cleaned water production can be achieved without any hazard pollutants. On the other hand, the treated wastewater can be reused safely for non-potable purposes for irrigation and / or flushing. Several studies in Egypt are also presented here.

Keywords: Water and wastewater management, Membrane technology, Water reuse, Water biotechnology.

Introduction

Membrane Technology is a new technique that can be employed for different applications in water treatment (surface water, sewage water, industrial wastewater, seawater, brackish water and reuse). It proved to be a powerful tool to abate the water crisis particularly in the Mediterranean

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region. It saves land area, efficient, and it retains all the biological contaminants. During the last three decades, this technology has received a lot of attention, resulting in an improvement of membrane materials and techniques, which showed higher fluxes, longer lifetime, partly improving the fouling and prolonged the time of membrane replacement. Thus, reduced the high costs. Although there is several national and international membranes research activities, lack of cooperation, very limited know-how exchange and an uncoordinated use of resources leads parallel and ineffective R&D activities.

During the last three decades, membrane technologies (MTs) have been increasingly employed for water / wastewater treatment and remediation due to the high-quality produced output and the compact design of the system [1]. In fact, MTs are developing rapidly as efficient and powerful tool to serve in the water crisis. These technologies are efficient in reducing the quality degradation of wastewater [2]. Both Industrial and municipal wastewater can be efficiently treated biologically by the Membrane Bioreactor (MBR) via membrane filtration and separation [3].

Conventionally treatment of wastewater is usually conducted via three successive processes, namely: sedimentation for the removal of the settable solids, followed by activated solids to serve for aerobic organic matter degradation and finally second sedimentation as polishing process for further removal of biomass. By using the MBR, the two physical sedimentation processes are replaced by separating or filtering the biomass particles. The MBRs technology is a combination of bio-treatment and membranes separation by the micro-filtration or ultra-filtration. Usually, the membrane is placed either inside the bioreactor or external. The MBR allows high level or concentration of Mixed Liquor Suspended Solids (MLSS) and produce low sludge. MBRs are able to remove TSS as wellas certain pollutants including chemical oxygen demand (COD) and biological oxygen demand (BOD) efficiently. Thus; in a single stage; MBRs produce clarified, high quality and largely disinfected permeate. Normally, the membranes have an effective pore size of <0.1 µm, that is smaller than the viruses and the pathogenic bacteria in wastewater [4].

The membrane filtration technique can be implemented in the wastewater treatment plants via variable applications processes. The membrane filtration system; generally; works perfectly as solid scavenger in the tertiary treatment step. The membranes; thus; became commercially a wide spread technologies for the treatment of industrial and municipal wastewaters as reliable and efficient system. The commercial market value of the membrane technologies was around US$217 million in 2005. The value increased to US$360 million at the end of 2008 [3]. The present estimated value is around US$650 million by the end of 2016. The annual growth rate in the market is around 11%.

Recently the combining of membrane technology with biological reactors for wastewaters treatment has led to the development of three main generic membrane bioreactors (MBRs). The three main generic purposes are separation and retention of solids; for bubble less aeration within the bioreactor and for extraction of organic pollutants from industrial wastewaters. The membranes as a biological process are mostly used to replace sedimentation, particularly for separating and retaining the biomass (Fig.1). Thus MBR is to keep biomass in the biological reactor (reactor performance) as well as mechanical disinfection to retain the biological contaminants (effluent hygienic quality). Such systems are well documented by many authors [5 - 7].

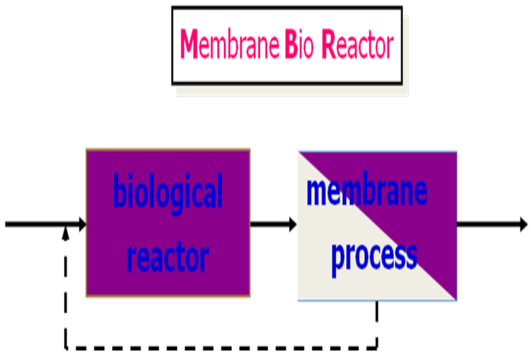


Fig. 1. Membrane Bioreactor is combination of both biological reactor and membrane process for filtration, separation and retaining the biomass.

Membrane mechanism

A membrane can be thought of as a material through which certain sizes of particles are allowed to pass through more readily than others. Such particles are presenting the basis of a separation process. Therefore, it is the main property of the membrane to separate components of certain size from water to be treated [4]. This is the key interest for designing or selecting a membrane in the water industry. In this respect, the membrane process acts in a way to reject pollutants and certain particle size that may be dissolved or suspended and to allow

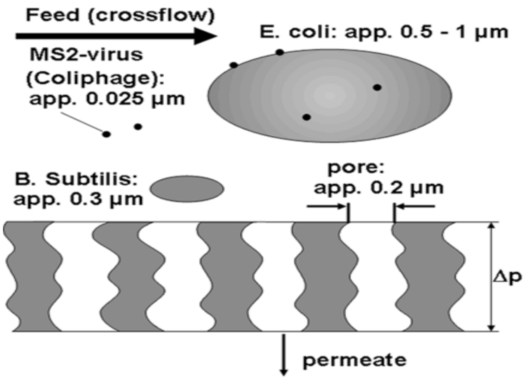


Fig. 2. Certain sizes of particles are allowed to pass through the membrane. The membrane process acts in a way to reject pollutants and certain particle size that may be dissolved or suspended and to allow the separated and purified water through,

the separated and purified water through (Fig.2)

Range of operation in the membrane processes

The main objective for manufacturing the membrane is to produce materials of high mechanical strength that can maintain a high throughout put of the desired permeate with excellent and high degree of selectivity. The last two characteristics are the most mutual counteractive, because they are responsible for a high degree of selectivity that is achievable by a membrane having small pore sizes to release high hydraulic resistance (or low permeability). Such permeability increases with increasing the density of the pores. The high material porosity is desirable. Thus, the overall membrane resistance is directly proportional to its thickness. Therefore, selectivity is compromised by a broad pore size distribution. Finally, the optimal physical structure for the membrane material should be based on a thin layer of material with a narrow range of pore sizes as well as high surface porosity .

It is worth mentioning that, the range of available membrane materials is very diverse. This range varies widely in both physical structure and chemical composition. Nevertheless, the most important property is the mechanism through which separation is actually achieved. Depending on this property, membranes are categorized as either dense or porous. Therefore, separation by dense membranes relies partially on physic-chemical interactions between the permeating components and the membrane material. These characteristics relate to separation processes and depending on the highest selectivity of separation [6]. Illustration of the submerged membrane modules is given in Fig.3..

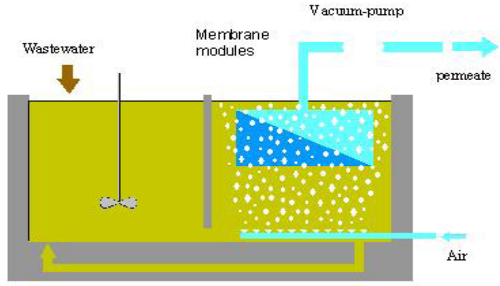


Fig. 3. Illustration of external submerged membrane filtration modules.

Membrane filtration, ultra-filtration, nano-filtration and reverse osmosis

Figure 4 illustrates the different filtration systems with respect to their separation of the particle size and the inserted pressure on the membrane system.

Microfiltration (MF) [2, 4]

Biomass, within the reactor thus produces a clarified effluent. MF is capable of removing only suspended materials – generally down to around 0.05 μm in size. Thus, MF is able to reject material.

Ultra filtration (UF) [2, 4]

It can remove colloidal and dissolved macro- molecules. It is, therefore, defined by the molecular weight cut-off in Daltons (i.e. the relative molecular weight) of the rejected solute, regardless to their physical size (Fig.5).

Nanofiltration and reverse osmosis

These processes are, therefore, able to separate ions from water. On the other hand, porous membranes achieve mechanical separation by sieving the same as the conventional filtration processes.

Nano-filtration Membrane System [2, 4]

Categorization of membranes depends on their material composition. Generally, the membrane material is either inorganic (ceramic or metallic) or organic (polymeric). The physical structure of the membrane based on the nature of these materials and/or the way of processing these materials. Such membrane materials that are employed in pressure-driven processes tend to be anisotropic. They, normally, have symmetry in one single direction so that their pore size varies with membrane depth. Only the very top layer of the membrane is actually demonstrates substantial selectivity. The remainder provides merely mechanical support. Figure 6 shows the nano-filtration pore size.

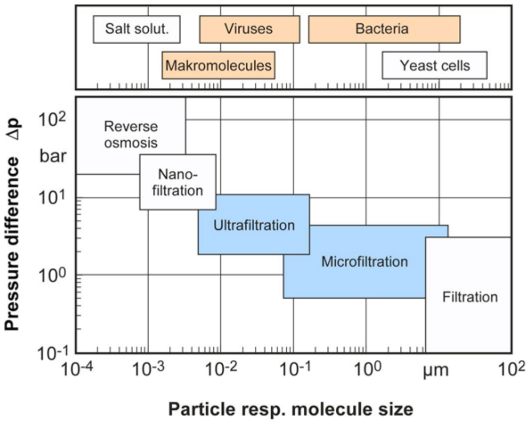


Fig. 4. Illustration of the different filtration systems with respect to their separation of the particle size and the inserted pressure.

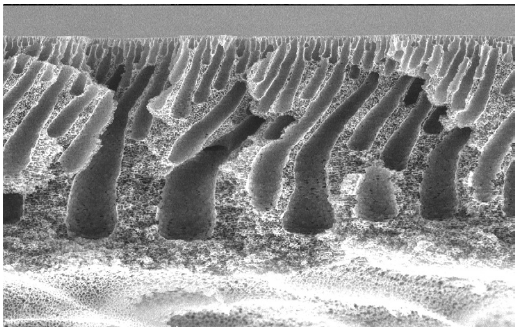


Fig. 5. The pore size of ultrafiltration membrane.

Manufacture of membrane refers, primarily, to the production of the porous materials. Therefore, the cost of the membrane is dependent not only on the raw material but also on the ease with which pores of the desired size or size distribution can be produced. This can vary considerably according to the different types of materials and the degree of isoporosity (*i.e.* the precision of the pore size distribution).

For instant, the inorganic membranes are formed by pressing and sintering of fine powders onto a pre-prepared porous support. It is a very expensive process particularly if a membrane layer of an even thickness and narrow pore size distribution is to be produced. The cost of ultra-filtration or micro-filtration membranes that are manufactured from titanium and/or zirconium may cost more than € 1600 per m². On the other hand, the homogenous polymeric membranes are produced by extrusion (stretching) of partly crystalline sheets perpendicular to the orientation of crystallites. This can be achieved by the assistance of a fiber agent, such as microscopic glass beads that promote the formation of pores. The production of these micro-porous materials cost less than € 15 per m². However, they are limited in their permeability, isoporosity and mechanical strength.

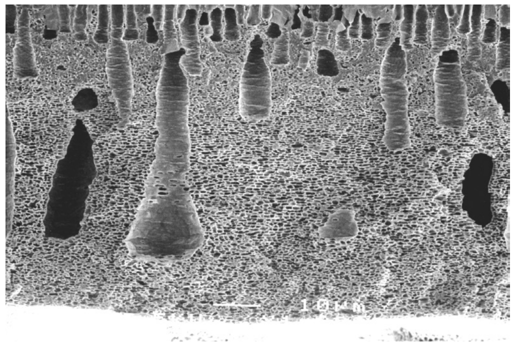


Fig. 6. the pore size of the membrane Nano-filter.

Membrane configuration and geometry

The way by which the membrane is shaped (*i.e.* the geometry of the membrane) is crucial and it is the main issue in determining the overall process performance. Furthermore, an important practical consideration is the way by which the membrane is housed in the treatment system or the “membrane modules” (*i.e.* whether the membrane is placed within the bioreactor or in external modules) as shown in Fig.3. Other factors are also important. One of these factors is promoting turbulence. However, the later results in an increase in the energy consumption. It is worth mentioning that direct mechanical cleaning of the membrane is possible only on a comparatively low area where the membrane is accessible. Furthermore, it is not possible to produce a high-membrane area to module bulk volume ratio without producing a unit that has narrow feed channels. This will adversely affect the cleaning regime and turbulence promotion. Meanwhile, the sludge retention time effects the microbial community structure in a membrane bioreactor [9].

Immersed membrane modules [8]

In terms of the cost for MBR, the preferable membrane materials are invariably polymeric. Nevertheless, geometries employed in key commercial systems range with respect to flat plate/ plate and frame (as in Kubota and

Rhodia Pleiade-based MBR system) to tubular (as in Milleniumpore) or hollow fiber (as in Zenon). The selection of the configuration is influenced greatly by the MBR process configuration and by the location of the membrane within the treatment system as whole.

Permeate flux and membrane area [9]

The flux is determined essentially by two factors, namely, the driving force and the total resistance of the membrane including the interfacial region adjacent to it. The resistance of the membrane is known and constant, unless it becomes partly fouled internally (or clogged) by the components in the feed water. On the other hand, the resistance of the interfacial region is a function of both feed water composition and the permeate flux. For the conventional pressure driven process, the materials rejected by the membrane is; usually; tend to be accumulated within the interfacial region at a rate dependent on the flux. These materials may cause fouling or clogging to the membrane through a number of physical-chemical mechanisms. Therefore, the process operational efficiency of a membrane is determined by certain extent to the force power that opposes the driving force predominate.

The generation of a cross flow velocity is decisive for a membrane filtration energy demand. The goal of the recent R&D activities is to minimize the energy requirement for the cross flow that is necessary to maintain the permeate flux on a high level. Thus, this operational and investment costs for the membrane can be minimized.

Activated sludge for conventional wastewater treatment plant [4]

The most common biological process for municipal wastewater treatment is the conventional activated sludge process (ASP). It was discovered in 1914 and was commercialized in 1920. Recently, ASP is well understood and is spread worldwide in different mathematical design and models. Nevertheless, the rising need for water reclamation and the stringent needs for effluent quality requirements in many countries are calling for further development of ASP. Such stringent needs are to fulfill the current legislation on wastewater treatment effluent. The purpose is to achieve higher removal of organic loads, suspended solids, nutrient elements, bacteria etc.

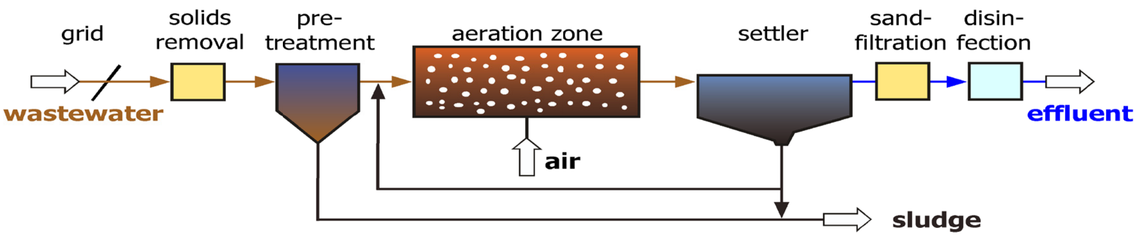
Therefore, several minimum standards of the effluent characteristics are set up by many countries. Requirements for the treated effluents depend on the type of using such water and / or whether it will be discharged to a receiving water. This includes the discharge to lagoons, rivers, lakes or aquifers. Thus the quality of treated effluent should meet the required standard

By using high purity oxygen or oxygen-enriched air the conventional aeration limitations can be overcome. This latter treatment increases the saturation of oxygen concentration (C*) with about 4.7 times. Thus greater volumetric degradation capacity can be achieved compared to conventional air aeration system. However, high cost of this oxygen, process should be considered.

Membrane bioreactor for wastewater treatment plant [2, 4, 8]

Employing membrane bioreactors (MBR) for wastewater treatment offers a great possibility of overcoming a lot of the current problems in activated sludge processes mainly due to the separation of biomass from the treated water. The settling process in MBR separating the biomass from treated water is replaced by micro- or ultra-filtration system. The membrane filtration step can be performed as external side-stream modules or submerged modules (Fig. 3) or directly immersed modules (Fig. 7) associated in the activated sludge tank. With a complete retention of bacteria and viruses, a very high quality of treated effluent will be obtained. Microbiological contaminants such as *Cryptosporidium Parvum* (25-µm) (Fig.8) and *Giardia Lamblia* (1012- µm) (Fig. 9) can be eliminated by employing membrane technology for the treatment of municipal wastewater. Meanwhile, it is possible to increase the biomass concentration considerably that results in decreasing the reactor volumes (*i.e.* a decrease in the sludge production rates).

The typical total suspended solids (TSS) concentrations in effluent of the MBR vary between 8 to 15 g/L and can be up to 40 g/L in the treated effluent of municipal and industrial wastewater respectively. Starting from the very first applications of MBRs for wastewater treatment during early 70´s, several MBR plants have been established over the last few years. Nowadays, many MBR treatment technical plants have been developed and; presently; they are in operation in different countries. However, there is still considerable development to be carried out for the optimization MBR processes. Figure 10 illustrates a compact MBR treatment system that was employed for the treatment of



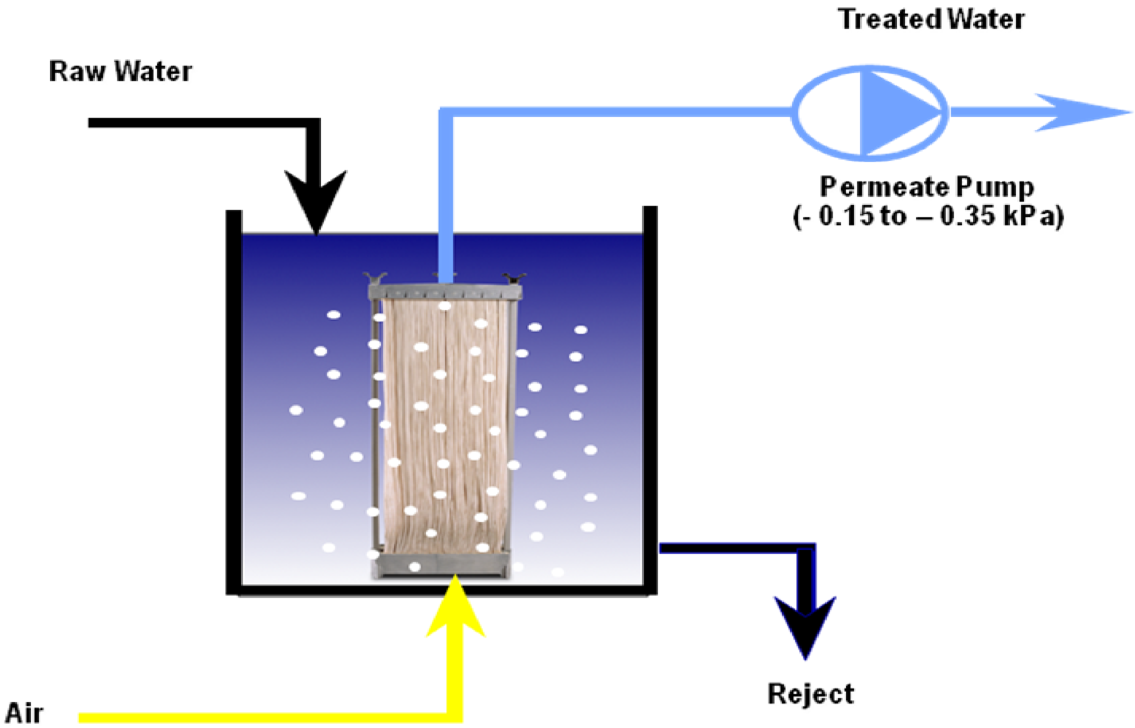


Fig. 7. The membrane filtration step can be performed as direct immersed modules associated in the activated sludge tank.

Fig. 8. Cryptosporidium Parvum (25- µm) can be retained by membrane technology for the treatment of municipal wastewater.

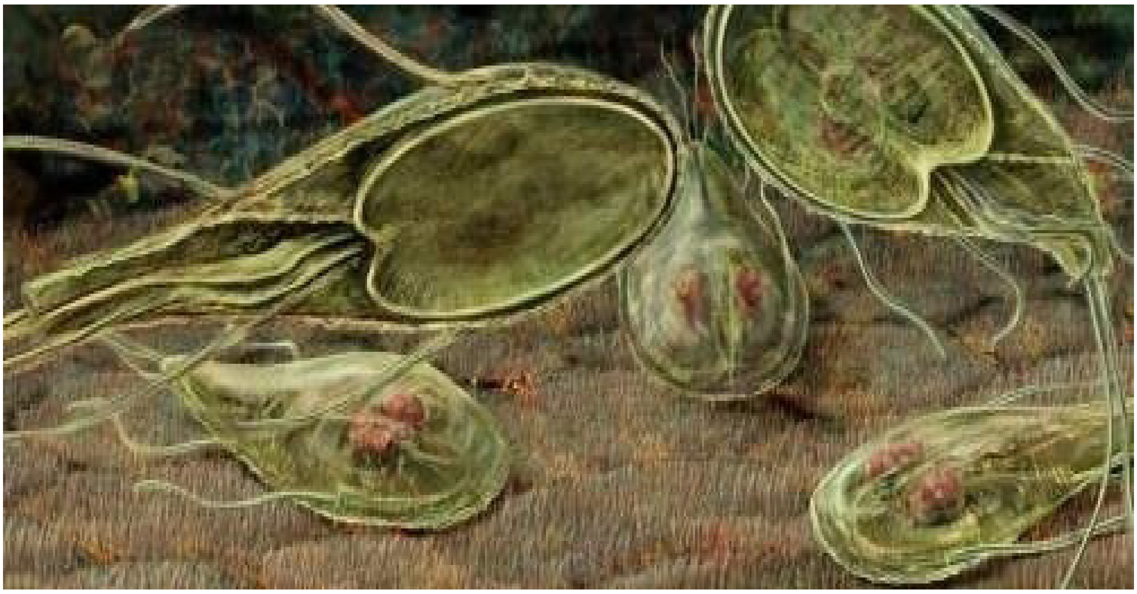


Fig. 9. Giardia Lamblia (1012-µm) can be retained by membrane technology for the treatment of municipal wastewater.

Fig. 10. illustration of MBR compact system for municipal wastewater treatment in Zenien Sewage Treatment Plant, Cairo, Egypt..

Efficiency of COD and BOD_5 removal in the Membrane Systems:

Due to the presence of activated sludge (AS) in MBRs as high number of microorganisms in the substrate, the reaction rate or the uptake can be accelerated. Thus, better degradation in a given time span can be achieved in the MBR reactor. Therefore, COD and BOD_5 removal rate increases as the concentration of the mixed liquid suspended solids (MLSS) increases. In case of the activated sludge process (ASP), the flocs may increase up to several 100 µm in size [9]. On the other hand, the hydrodynamic stress in MBRs reduces flock size to 3.5 µm inside stream [10], thus increases the apparent reaction rate.[9]

The organic loads in the effluent of the MBR are always within the required standard. Usually, the recorded BOD_5 effluent is less than < 10 $mg.L^{-1}$. This high BOD_5 removal rates is attributed to the complete particulate retention of suspended COD and $BOD_{5.}$ Meanwhile, no washout problems in the MBR process as encountered in ASP [5].

Rates of nitrification in MBR

It is well known that the amount of energy that could be gained by nitrification is relatively low. The nitrifiers are slow growing in the MBR . In order to ensure complete nitrification, it is essential to reach a minimum sludge age of > 5 days [11]. Due to this fact, the design of MBR treatment plants is based on a minimum sludge retention time (SRT) of 8 to 10 days at 10 °C [11].

Nitrification is an aerobic process in which oxygen as the electron acceptor is employed thus the process could take place. It was reported by Charley et al. [12] that the half-saturation constant for dissolved oxygen (D.O.) should be within the range between 0.3 and 1.3 mg.L^{-1}. Generally, the MBR treatment plants are operated at high MLSS concentrations. This leads to change of rheology and an increase in viscosity [13]. Consequently, the degree of mixing decreases and micro anoxic zones can be formed where no oxygen is present in the aerated tank. This results in simultaneous denitrification. On the mean time, the increase of MLSS concentrations increases the sludge viscosity. This causes problems with the performance of the membrane, thus oxygen mass transfer rate decreases [14]. This matter leads to optimal MLSS concentrations for the most efficient MBR process of about 15 g.L^{-1}. Typically MBR operating plants reach the total nitrification in the treated effluent with ammonium concentrations below 1 mg (NH_4-N) L^{-1}.

The maximum rates of the reported specific nitrification are 0.78 to 1.81 mg NO_3-N $(gSS.h)^{-1}$ for synthetic wastewater, 0.91 to 1.12 mg NO_3-N $(gVSS\ h)^{-1}$ for domestic wastewater and 1.7 to 2.0 mg NO_3-N $(gVSS.h)^{-1}$ for the municipal wastewater [11, 15]. Nevertheless, the recorded average nitrification activity was more than twice that of activated sludge process (ASP) namely, 2.28 g NH_4- N $(kgMLSS\ h)^{-1}$ for MBR process compared to 0.96 g NH_4-N $(kgMLSS.h)^{-1}$ for the ASP [16].

Efficiency of MBR and degree of removal

By comparing the MBR and ASP we find that the sludge ages or SRTs by MBR processes is slightly exceeding that of ASP. On the other hand, the hydraulic retention times (HRTs) in MBR are within the same range of ASP and are around 15 kg.m^{-3}. Meanwhile, the MLSS concentrations in the MBR plant are three times (3X) higher than in activated sludge process. (ASP) [16] Accordingly, the organic loading rates as BOD_5 can be increased in a similar range.

Sludge in MBR Process

Increase the sludge age is among the ways for reducing the sludge yield in aerobic systems for the purpose of decreasing the waste rate. The organic substrate contents are consumed by the micro-organisms to synthesis more biomass; in one hand; and to maintain their cells; on the other hand. In the anaerobic system, the waste gases are methane and carbon dioxide. In the anoxic system, the produced gases are nitrogen and carbon dioxide. Furthermore, the aerobic system produces carbon dioxide. Thus, the higher the yield coefficient encourages more biomass production. As a result, less carbon dioxide can be produced from the substrate degradation.

Technically, no significant decrease in the sludge production was recorded for sludge ages less than < 30 d in the wastewater treatment plants (WWTP) [17]. It was reported that decreasing the sludge to significant level it needs to increase sludge age to > 100 d [22]. In Australian WWTP using MBR 0.48 kg MLSS $(kg\ COD)^{-1}$ was produced including the precipitation solids. By using the conventional activated sludge process in the same plant, it was found that the biological sludge yield was 0.25 kg MLSS $(kg\ COD)^{-1}$ [18].

Viscosity of Sludge in MBR

By measuring the Rheological characteristics of a highly concentrated activated sludge of MBR the results exhibited a strongly pseudo plastic behavior. This indicates that the activated sludge of MBR should be regarded as non-Newtonian fluids. The value of the viscosity varies to factor 10 and even up to 100 (*i.e.* varies between low and high rates). In addition, the MBR activated sludge shows slightly time-dependent rheological characteristics. The thixotropic and pseudoplastic behaviour can be explained by the bioparticulate structure of the activated sludge. Generally, the particles of the sludge tend to flocculate to form a large-scale network. When the shear rate increase, the particles network is disrupted and aligned. This induces a decrease in viscosity of the system.

It is worth mentioning that the MBR operation is greatly affected by the non-Newtonian characteristic of the highly concentrated activated sludge. Such effects are represented in the areas with low convection viscosity that increases by one or two orders of magnitude. This impact could likely form few dead zones, thus decrease the effective volume of the activated sludge in the MBR. As a result the formed clogs of the membrane are difficult to remove without additional energy to be inserted to the system. Therefore, increasing the viscosity increases the energy consumption, thus, limiting the economical advantage of the MBR. The conclusion is that membrane operation under higher viscosity induces high energy consumption that is necessary for both mixing and convection along the membrane surface and for air mass transfer [13].

Impact of fouling on declining the flux

Fouling is the term that expresses the process of membrane resistance. Fouling is a variety of species that are present in the water to increase such membrane resistance. It includes depositing or adsorbing on the membrane surface, complete pore-blocking of membrane materials, or adsorption onto the pore surfaces (membrane pore restriction). Several physical, chemical and biological mechanisms are responsible for fouling. The physical and chemical fouling (*i.e.* not related to biological growth) is attributed to both colloidal/particulate materials and proteins in the wastewater [5].

What is fouling?

Fouling is the blocking, restriction or occlusion of the pores at the surface of the membrane; thus; reducing the flow of permeate water through the membrane material [3]. Sometime, channel clogging, is referred to as "sludging", is the filling of the channels between membranes with sludge as solid residues that restricts the flow of water over the membrane surface. A membrane fouling is (8%) pore clogging and (80%) sludge cake layer deposition on the membrane pore [19]. The membrane fouling induce a reduction of permeate flux and an increase of trans-membrane pressure (TMP) [19]. The sludge layer cake is the main cause that leads to membrane fouling.

Indeed, despite their proven effectiveness, the major cause that hinders of the economic use of membrane techniques in developing countries is the phenomenon of bio-fouling. This phenomenon causes clogging of the membrane pores. Thus, causes additional costs for operations and maintenance represented by over-consumption of energy as well as frequent cleaning and / or replacement of the membranes.

Nevertheless, membrane fouling is the main drawback hindering the wide application of the membrane system. It leads to decrease membrane flux and to increase filtration pressure and subsequently increased operation cost due to frequent cleaning and replacement of the clogged membrane [20 - 22]. The fouling problem is still confused despite of lot of work published in this subject [3]. It is well known that the most significant cost MBRs operation is membrane replacement and energy consumption. Both are strongly related to fouling [3].

Fouling management and controlling

Controlling the fouling problem could be achieved by four ways: (a) promotion or increasing of the liquid turbulence, this could limit greatly the thickness of the hydrodynamic boundary layer (b) reduction of the flux, (c) pretreatment of the wastewater or in-treatment, and (d) regular membrane cleaning to remove any foulants. However, all these options are adding to the operation cost. Nevertheless, it is essential to optimize the system and to prevent it from such fouling problem in a way without excessive operation cost. Practically, placing the MBR externally at a high cross-flow is one solution. Meanwhile, flux reduction can also be achieved by submerging the MBR, thus; limits the degree of possible turbulence promotion in another hand. Therefore, the design of MBR in wastewater treatment plants, membrane surface area should be set up in a linear relation with the flow rate

The advantages and disadvantages of MBRs:

Employing of MBR for wastewater treatment has the following advantages.

Advantages

- Good effluent quality with high hygienic standards will be obtained,
- High possible biomass concentration (10-25 g MLSS/L),
- Reduced reactor volume and footprint, thus limited area is required in wastewater treatment plant,
- Reduced net sludge production,
- Reduce almost the total solids,
- Remove most of the drug residues from wastewater,
- Increases the process capacity of plant without extension of land area,
- The MBR plant does not need the secondary clarifier, thus the area and cost of such clarifier is saved .
- No chemical addition is required for disinfection.

Disadvantages

- Relatively high investment costs of embrane

modules,
- Membrane integrity (failure detection, lifetime),
- High operating costs (due to energy consumption).

Application of MBR in Egypt

Membrane technologies are still not widely used in Egypt. However, there are some scattered units that are employed in certain remote areas for desalination purposes. On the contrary, membranes are moderately studies and investigated on the research areas by several scientists and researchers. Despite of these research activities, the general trend in membrane research is not satisfactory [2]. Full-scale membrane treatment plants do not actually exist in the Egypt so far. Implementing membrane technologies in the Middle East and North African (MENA) countries has particular relevance to the decision makers [23]..

On the research side, some of different activities are presented here .

Membrane micro-filtration for the removal of some pharmaceutical compounds from urine[24]

In a semi-pilot plant study; membrane micro-filtration was implemented to remove some pharmaceutical compounds from the separated urine. The pilot plant consisted of mixing tank for chemical coagulation using ZnO nanoparticles and the effluent was subjected to membrane microfiltration unit (Fig. 11). The system was studied in a continuous operating unit for the treatment of the separated urine. The overall results of the semi-pilot study showed efficient removal over 95% of the studied pharmaceutical compounds from urine [24].

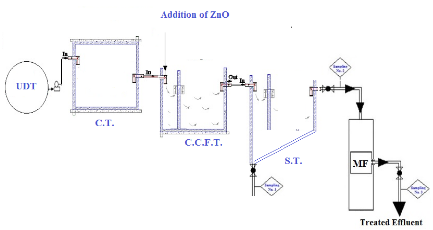


Fig. 11. Schematic diagram of the semi-pilot plant for the removal of pharmaceutical compounds from separated urine (UDT, C.T., C.C.F.T., S.T. and M.F. are the urine diversion toilet, Uririne collection tank, chemical coagulation & flocculation tank, settling tank and the membrane micro-filtration reactor, respectively) [24].

Extraction of hydroxytyrosol from olive mill wastewater [25]

In this study recovery and concentration of antioxidant was conducted successfully from olive mill wastewater. For this purpose integrated membrane systems were employed using β-glycosidase as enzymatic hydrolysis followed by acid hydrolysis. Thus, higher concentration of pure hydroxytyrosol (HT) was released. In this study, olive mill wastewater (OMW) was subjected directly to a microfiltration (MF). The obtained permeate was further subjected to ultra-filtration (UF). Another portion of the MF permeate was further subjected to nano-filtration (NF). The polyphenols in raw OMW was recovered and concentrated in the Retentate of the successive membranes filtration units namely MF, UF and NF. However, almost all polyphenol compounds were recovered and concentrated in the NF Retentate solution. By employing the NF in combination with the enzymatic hydrolysis, pure HT could be obtained. The study proved that integrated membrane technologies are excellent tools to release the valuable phenolic compounds from OMW [25]. The removal percentage of the polyphenol compounds by applying different membrane systems is given in Fig. 12..

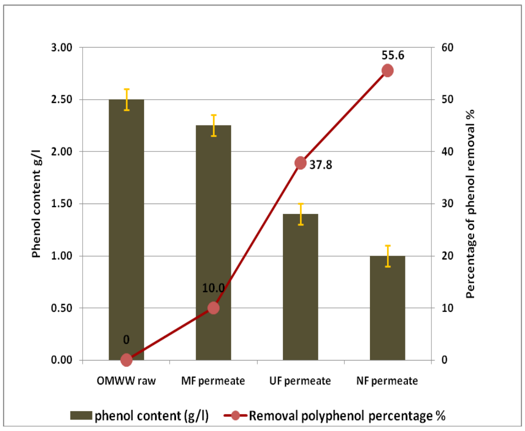


Fig. 12. Removal percentage of the polyphenol compounds by applying different membrane systems [25].

Membrane bioreactor for the treatment of blackwater [4]

The efficiency of the membrane bioreactor (MBR) for the treatment of blackwater was studied in a pilot-scale. The MBR was installed and operated in the National Research Center (NRC), Cairo, Egypt. Blackwater was separated by piping system and connected through manhole to the NRC. The blackwater was first primary treated by three chambers baffled settling tanks. The effluent was further treated by MBR. The schematic diagram of the treatment train is illustrated in Fig. 13. Removal of the pollution parameters namely TSS, COD and BOD ranged from 90 to 97%. The removal percentage of TKN and ammonia was 94% and 97% respectively. This investigation demonstrated the advantages of membrane technologies in correlation with the activated sludge treatment system. The investigators expected that the decision maker would be encourage to invest in the membrane technologies due to their potential application for wastewater treatment where the treated effluent can be used safely for irrigation purpose in Egypt [4]. The MBR pilot plant that was employed in this study is given in Fig. 14.

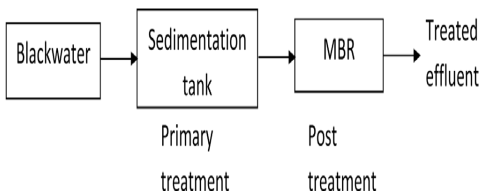


Fig. 13. Schematic diagram train for the blackwater treatment via membrane bioreactor.

Fig. 14. The MBR pilot unit for the treatment of blackwater in Egypt [4].

Membrane bioreactor for the treatment of municipal wastewater in Egyptian climate [17]

In a study that was operated at Zenien sewage treatment plant, Giza, Cairo, the MBR was employed for the treatment of municipal wastewater under the conditions of the Egyptian climate. Results obtained showed significant improvement in the quality of the final effluent in terms of TSS, BOD, COD, nitrogen compounds, phosphates, E.C., D.O. and heavy metals. Furthermore, the recorded results exhibited a complete retention of bacteria including pathogens. Therefore no restrictions concerning the reuse of such treated effluent for crop irrigation [17]. Figure 10 illustrated the pilot plant that was employed for this study.

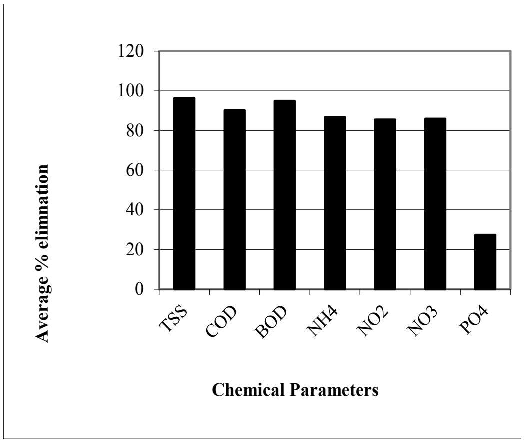


Fig. 15. Average percent elimination of the chemical Characteristics [17].

Molecular imprinted Membrane for separation of polycyclic aromatic hydrocarbon [26)]

Further study was conducted concerning the "Molecular Imprinted Membrane" based on molecular imprinted NanoParticles Polymers [26]. The purpose of the study is to separate the "Polycyclic Aromatic Hydrocarbons" by phase inversion technique. Anthracene molecular imprinted membrane (An–MIM) was synthesis by hybridizing anthracene molecular imprinted polymer (An–MIPs) nanoparticles with cellulose acetate (CA). The physical characterization of the synthesized An–MIM and cellulose acetate membrane (CAM) was carried out using Fourier Transform Infrared Spectroscopy (FTIR) and Scanning Electron Microscope (SEM).

The binding capacities of An–MIM for Anthracene, Naphthalene, Pyrene, Benzo(a) pyrene, Phenanthrene and Acenaphthylene were determined. Furthermore, the values of binding capacity of CAM for Anthracene, Naphthalene, Pyrene, Benzo(a)pyrene, Phenanthrene and Acenaphthylene were also investigated in mg/g.

In addition, the separation properties of An–MIM and CAM were studied as well as the selectivity factors of An–MIM for Naphthalene, Pyrene, Benzo(a)pyrene, Phenanthrene and Acenaphthylene with respect to anthracene were also determined. The rejection percentages of An–MIM towards Anthracene, Naphthalene, Pyrene, Benzo(a)pyrene, Phenanthrene and Acenaphthylene were also studied. Furthermore, the rejection percentages of An–MIM towards Anthracene, Naphthalene, Pyrene, Benzo(a) pyrene, Phenanthrene and Acenaphthylene were investigated. The determined concentration factor of Anthracene–MIM and CAM were 7.9 and 0.8 respectively. The optimum time of operation was 3hr for An–MIM.

It was concluded from the overall results that the presence of chemical binding sites in the An–MIM plays predominating role in terms of the separation properties. Furthermore, An–MIM was proved to be highly efficient for the elimination of the polycyclic aromatic hydrocarbons at different percentages. Figure 16 illustrates the Flow diagram of the laboratory scale membrane unit for separating the polycyclic aromatic hydrocarbons.

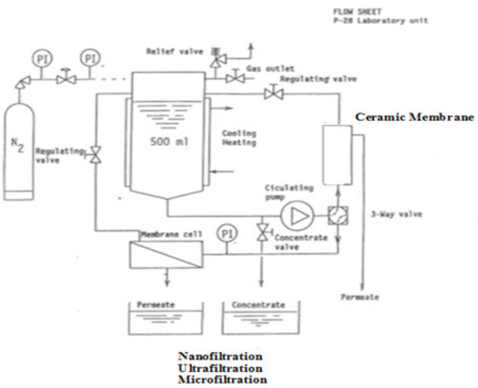


Fig. 16 . The Flow diagram of the laboratory scale membrane unit for separating the polycyclic aromatic hydrocarbons [26].

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تكنولوجيا الاغشية المسامية لمعالجة المياه والمخلفات السائلة وتطبيقاتها في مصر

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في الاونة الحديثة اصبحت تكنولوجيا الاغشية المسامية من اهم التقنيات المستخدمة في معالجة المياه والمخلفات السائلة , وخاصة ان هذه التقنية قادرة على ازالة التلوث الكيميائي والبيولوجي على حد سواء بما في ذلك الكائنات الحية الدقيقة . ويصبح ناتج المعالجة مياه صالحة لاعادة استخدامها بشكل امن وبطريقة عملية من الناحية الاقتصادية.

وكما هو معروف فان مصر تهدف الى تعظيم الاستفادة من جميع مصادر المياه خاصة ان الدخل المائي لمصر مقبل على مرحلة حرجة. لذلك فان استخدام هذه التقمية ممكن ان يكون حلا عمليا ذو كفاءة عالية في معالجة المياه والمخلفات السائلة. فعلى مدار دراسات بحثية لمدة اكثر من ٣٠ عاما تم تطوير هذه التقنية لتصبح اكثر فاعيله ف استخدامها واقل تكلفة .

في البحث الحالي نطرح منظومة كاملة لشرح الاوجه المختلفة لتكنولوجيا الاغشية المسامية بجميع انواعها وتطبيقاتها المختلفة والهدف من استخدامها. فالناتج الفعلي من مزايا هذه التقنية بطريقه علمية وعمليه مع التوضيح بالرسومات لكل منها. كما تتعرض الدراسة لاهم البحوث التي تمت في نفس هذا المجال .